CHAPTER 3 Gravitation

Gravitation is the weakest force in nature. It is negligible in the interactions of tiny particles, and thus plays no role in molecules, atoms, and nuclei. The gravitational attraction between objects of ordinary size, such as the gravitational force exerted by a building on a car, is too small to be noticed. When we consider very large objects, such as stars, planets, and satellites (moons), gravitation is of primary importance. The gravitational force exerted by the earth on us and on the objects around us is a fundamental part of our experience. It is gravitation that binds us to the earth and keeps the earth and the other planets on course within the solar system. The gravitational force plays an important role in the life history of stars and in the behaviour of galaxies.

3.1 The Newtonian gravitation

Sir Isaac Newton did not discover gravitation, its effects have been known throughout human existence. But he was the first one to understand the broader significance of gravitation. Newton discovered that 'gravitation is universal, it is not restricted to earth only', as other physicists of his time assumed.

Newton's universal law of gravitation

'Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. The force is along the line joining the centres of two objects'.

Let us consider two masses m_1 and m_2 lying at a separation distance r. Let the force of attraction between two objects be F. According to the universal law of gravitation,

$$F \propto m_1 m_2$$

$$F \propto \frac{1}{r^2}$$

Combining both, we get, $F \propto \frac{m_1 m_2}{r^2}$

or $\boxed{F = \frac{G m_1 m_2}{r^2}}$

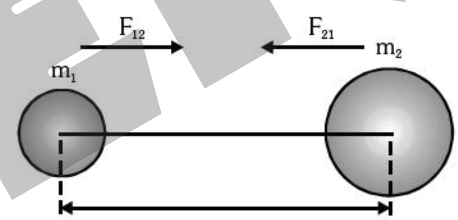


Fig. 1 Newton's law of gravitation

Where, G is the constant of proportionality and is called the universal gravitation constant.

- Universal gravitation constant is the magnitude of the force (in newton) between a pair of 1 kg masses that are kept 1 meter apart.

  Unit of universal gravitation constant : According to the universal law of gravitation,

$$F = \frac{G m_1 m_2}{r^2} \quad \text{or} \quad G = \frac{Fr^2}{m_1 m_2}$$

Thus, S.I. unit of $G = \frac{\text{Newton} \times (\text{meter})^2}{\text{kg} \times \text{kg}} = \frac{\text{Nm}^2}{\text{kg}^2} = \text{Nm}^2\text{kg}^{-2}$

- The value of the constant G is so small that it could not be determined by Newton or his contemporary experimentalists. It was determined by Henry Cavendish for the first time (1798) about 200 years earlier. Its accepted value today is 6.673×10^{-11} $\text{Nm}^2\text{kg}^{-2}$. It is because of the smallness of G that the gravitational force due to ordinary objects is not felt by us.

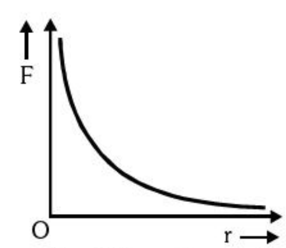


Fig. 2 Dependence of gravitational force (F) on separation distance (r).

Characteristics of gravitational force :

(1) It is a universal force of attraction.

(2) It acts along the line joining the centres of each mass.

(3) It acts equally on each mass, i.e., it obeys Newton's third law i.e., $F_{12} = -F_{21}$

(4) It is weaker if the masses are further apart. It acts in an inverse square manner, i.e., $F \propto \frac{1}{r^2}$, where 'r' is the distance between the centres of the masses.

(5) It depends directly on the mass of each body involved, i.e., $F \propto m_1$ and $F \propto m_2$.

(6) It is a long range force i.e., its influence is extending to very large distances.

(7) It does not depend on the medium present between the two masses.

(8) The Newton's universal law of gravitation successfully explained several phenomena which were believed to be unconnected :

(i) The force that binds us to the earth. (ii) The motion of the moon around the earth.

(iii) The motion of planets around the Sun. (iv) The tides due to the moon and the Sun.

Why moon does not fall on earth directly ?

The motion of moon is just like the motion of an object in circular motion. The velocity of the moon is directed tangent to the circle at every point along its path. The acceleration of moon is directed towards the center of the circle i.e., towards the earth (the central body) around which it is orbiting. This acceleration is caused by a centripetal force which is supplied by the gravitational force between the earth and the moon. If this force was absent, the moon in motion would continue in motion at the same speed and in a direction tangential to the circular path and would have escaped away from the earth. If the moon had no tangential velocity, it would have fallen on earth due to gravitation. Thus, it is the tangential velocity and the gravitational force that are perpendicular to each other and keep the moon to fall around the earth without actually falling into it.

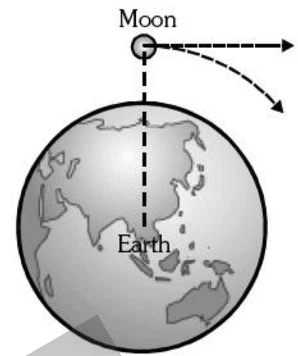


Fig.3 The Earth-Moon system

NUMERICAL CHALLENGE 3.1

Find the distance between a 0.300 kg billiard ball and a 0.400 kg billiard ball if the magnitude of the gravitational force between them is 8.80×10^{-11} N. Take, G = 6.6×10^{-11} Nm^2kg^{-2}.

Solution

Given, $m_1 = 0.3$ kg ; $m_2 = 0.4$ kg ; $F = 8.80 \times 10^{-11}$ N ; r = ?

According to Newton's law of gravitation, $F = \frac{Gm_1m_2}{r^2}$

or $r^2 = \frac{Gm_1m_2}{F} = \frac{(6.6\times10^{-11})(0.3)(0.4)}{8.8\times10^{-11}} = 0.09$

or r = **0.3 m**

3.2 Kepler's laws of planetary motion

Law of orbits : All planets move in elliptical orbits with the Sun situated at one of the foci of the ellipse (see fig.4). The closest point is P called the **perihelion** and the farthest point is A called the **aphelion**. The semimajor axis (R) is half the distance AP.

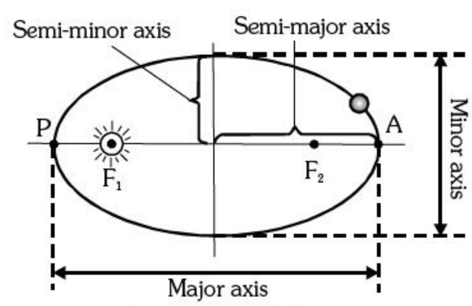


Fig.4 Law of orbits

Law of areas : The line that joins any planet to the sun sweeps (see fig.5) equal areas in equal intervals of time i.e., $\frac{\Delta A}{\Delta t} = \text{constant}$. This means, the planet moves faster when it is nearer to the Sun and it moves slower when it is farther from the Sun i.e. ($v \propto 1/r$).

For example, $\boxed{\frac{v_A}{v_P} = \frac{r_P}{r_A}}$. Since $r_A > r_P$, $v_A < v_P$.

Law of periods : The square of the time period of revolution of a planet is proportional to the cube of the semi-major axis (mean distance) of the ellipse traced out by the planet i.e.,

$T^2 \propto R^3$ or $\frac{T^2}{R^3} = \text{constant}$. Also, $\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{R_1}{R_2}\right)^3$

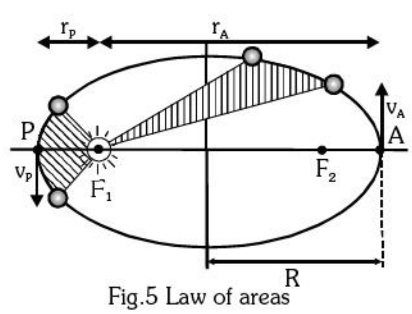


Fig.5 Law of areas

3.3 Acceleration due to gravity

The constant acceleration of a freely falling body is called the acceleration due to gravity. It is the acceleration of an object in free fall that results from the influence of Earth's gravity. Its magnitude is denoted with the letter g.

Acceleration due to gravity at the surface of earth

Let us consider an object of mass m placed on the surface of Earth. Let the mass of Earth be M and radius of earth be R. The gravitational force on the object due to Earth is given by,

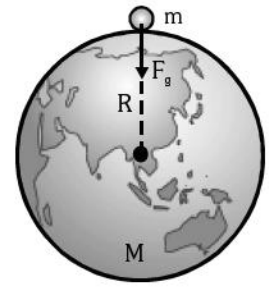


Fig.6 Acceleration due to gravity

$F_g = \frac{GmM}{R^2}$ ...(1)

Let this force produces an acceleration 'a' in the object, then,

$F_g = ma$ ...(2)

From eq.(1) and eq.(2), we get,

$$ma = \frac{GmM}{R^2}$$

$$\text{or} \quad a = \frac{GM}{R^2}$$

This acceleration is called acceleration due to gravity and it is denoted by g i.e., a = g.

$$\therefore \quad \boxed{g = \frac{GM}{R^2}}$$

■ The acceleration due to gravity g for any planet is (i) directly proportional to the mass of the planet (ii) inversely proportional to the square of the radius of the planet.

Acceleration due to gravity (g) on earth is 9.8 ms^{-2}. In Cgs system, value of g is 980 cm/s^2. In fps system, value of g is 32 ft/s^2.

- Among the planets, value of 'g' is maximum for Jupiter, $g_{Jupiter} = 26\ m/s^2$.
- For two planets 1 and 2, ratio of their acceleration due to gravity, $\frac{g_2}{g_1} = \frac{M_2 R_1^2}{M_1 R_2^2}$

NUMERICAL CHALLENGE 3.2

The radius of the Earth shrinks by 10 %. By how much percent the acceleration due to gravity on the Earth's surface would (mass remaining constant) change ?

Solution

Initial radius = r ; mass of Earth remains constant = M

New radius, $r' = r - \frac{10}{100}r = \frac{90}{100}r = 0.9r$

Initial value of acceleration due to gravity, $g = \frac{GM}{r^2}$

New value of acceleration due to gravity, $g' = \frac{GM}{(r')^2} = \frac{GM}{(0.9r)^2} = \frac{1}{0.81}\left(\frac{GM}{r^2}\right) = \frac{1}{0.81}g$

Percentage change in the value of acceleration due to gravity is given by,

$$\frac{g' - g}{g} \times 100 = \frac{(1/0.81)g - g}{g} \times 100$$

$= \left(\frac{1}{0.81} - 1\right) \times 100 = +\frac{0.19}{0.81} \times 100 = +23.45\ \%$ Positive sign shows that there is an increase in the value of g. The value of g increases by **23.45%**.

3.4 Factors affecting acceleration due to gravity

Shape of Earth

Our earth is not perfectly spherical. The radius of earth at poles (R_p) is slightly smaller than the radius of earth at equator (R_E).

$$g_P = \frac{GM}{R_P^2} \text{ --- (1)} \quad \text{and} \quad g_E = \frac{GM}{R_E^2} \text{ --- (2)}$$

$$\frac{(1)}{(2)} \Rightarrow \frac{g_P}{g_E} = \frac{GM/R_P^2}{GM/R_E^2} \quad \text{or} \quad \frac{g_P}{g_E} = \frac{R_E^2}{R_P^2} \text{ --- (3)}$$

Since, $R_E > R_p$, therefore, $g_p > g_E$.

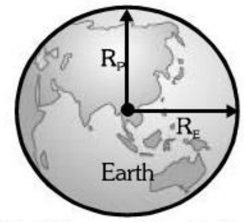


Fig.7 Shape of the Earth is not perfectly spherical, $R_P < R_E$

Rotation of Earth

Rotation of earth also affects the value of acceleration due to gravity at place on the surface of earth. Because of rotation, an object experiences a centrifugal force acting away from the axis of rotation which varies from place to place on the Earth. This centrifugal force is maximum at equator and minimum (zero) at the poles. As a result, value of g at equator is minimum and value of g at poles is maximum. Thus, because of rotation, $g_P > g_E$.

- As we move from a place on equator to a place on pole, value of g increases. In other words, if latitude angle increases from 0° (equator) to 90° (poles), g also increases.
- If rotation of earth stops, value of g will increase at the equator while it will remain unchanged at the poles.

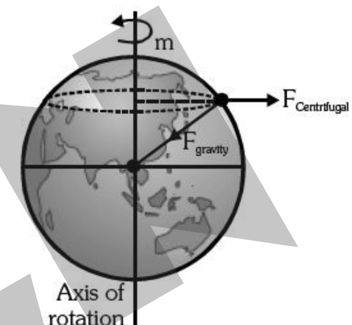


Fig.8 Rotation of Earth affects acceleration due to gravity

■ Considering the shape of the Earth and its rotation, we can conclude that acceleration due to gravity on the surface of earth is maximum at the poles and minimum at the equator.

Height above the surface of earth

$$g_A = \frac{GM}{(R+h)^2} = \frac{gR^2}{(R+h)^2} \quad \text{(see fig.9)}$$

- For $h << R$, i.e., a point very near the surface,

$$g_A = g\left(1 - \frac{2h}{R}\right)$$

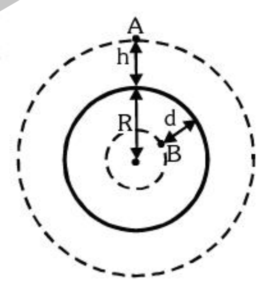


Fig.9 Effect of height (or depth) above (or below) the surface of Earth

Depth below the surface of earth

$$g_B = g\left(1 - \frac{d}{R}\right) \quad \text{(see fig.9)}$$

- At the centre of Earth, d = R thus, value of g at the centre is,

$$g_{Centre} = g\left(1 - \frac{R}{R}\right) = g(1-1) = 0$$

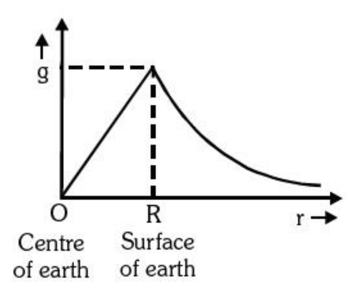


Fig.10 Variation in g with distance from the centre of Earth

■ Acceleration due to gravity on the moon is one sixth of the acceleration due to gravity on the earth i.e.,

$$\frac{g_m}{g_e} = \frac{1}{6}$$

Thus, weight of the object on the moon = (1/6) × its weight on the earth.

3.5 Gravitational potential energy

Gravitational potential energy between two masses m_1 and m_2 having distance r between them is,

$$U = -\frac{Gm_1m_2}{r}$$

- Gravitational potential energy is always negative, the negative sign shows its attractive nature.

Gravitational potential energy of a system of n particles can be written as

$$U = -G\sum_{\substack{i\neq j \\ \text{All pairs}}} \frac{m_i m_j}{r_{ij}}$$

For example, for a three particle system (see fig.11),

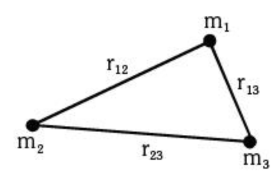


Fig.11 Gravitational potential energy of three particle system

$$U = -\frac{Gm_1m_2}{r_{12}} - \frac{Gm_2m_3}{r_{23}} - \frac{Gm_1m_3}{r_{13}}$$

- Gravitational potential energy of an object located at a height h above the surface of Earth is given by,

$$U = -\frac{GMm}{(R+h)}$$ Where, M = mass of Earth ; m = mass of object ; R = radius of earth.

- Gravitational potential energy of a particle located on the surface of earth,

$$U = -\frac{GMm}{R}$$

3.6 Orbital velocity

The speed of a satellite, spacecraft, or other body travelling in an orbit around the earth is called **orbital velocity**.

$$v_O = \sqrt{\frac{GM}{(R+h)}} = \sqrt{\frac{gR^2}{(R+h)}}$$ (see fig.12)

- For a satellite orbiting quite near to the earth,

$$v_O = \sqrt{\frac{GM}{R}} = \sqrt{gR} \approx 8 \text{ km/s}$$

- Time period of a satellite orbiting around the earth in a circular path,

$$T = 2\pi\sqrt{\frac{(R+h)^3}{GM}} = 2\pi\sqrt{\frac{(R+h)^3}{gR^2}}$$

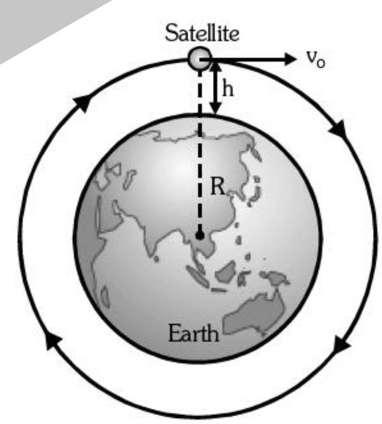


Fig.12 Orbital velocity of a satellite

- Time period of a satellite orbiting very near to the surface of earth in a circular path,

$$T = 2\pi\sqrt{\frac{R^3}{GM}} = 2\pi\sqrt{\frac{R}{g}} \approx 85 \text{ minutes}$$

Geostationary orbit

It is an orbit of the earth made by an artificial satellite with a period exactly equal to the earth's period of rotation on its axis, i.e., 24 hours. If the orbit lies in the equatorial plane and is circular, the satellite will appear to be stationary. This is called a stationary orbit (or geostationary orbit) and it occurs at an altitude of 35800 km. Most communication satellites are in stationary orbits, with three or more spaced round the orbit to give worldwide coverage. Such satellites are called **geostationary satellites**.

Polar satellites

These are low altitude satellites (h is nearly 500 to 800 km), but they go around the poles of the earth in a north-south direction whereas the earth rotates around its axis in an east-west direction. Their time period is around 100 minutes and they cross any latitude many times a day.

3.7 Escape speed (or velocity)

The minimum speed needed by an object like space vehicle, rocket, etc., to escape from the gravitational field of the earth, moon, or other celestial body is called escape speed or velocity (v_e).

$$v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

Some important points related to escape velocity are :

(1) Escape velocity is independent of the mass of the object projected from the Earth. For example, a spacecraft has the same escape speed as a molecule.

(2) Escape velocity is independent of the direction of the velocity.

(3) Escape velocity for earth is about 11.2 km/s. Escape velocity for moon is about 2.3 km/s, nearly five times smaller than that of earth. Among the planets, escape velocity is maximum for Jupiter, it is 59.5 km/s.

EXERCISE

Multiple choice questions

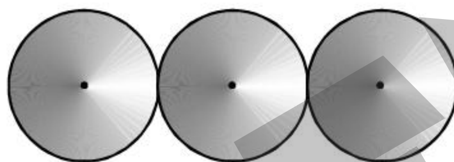
1. Two metal spheres of equal radius r and equal densities are touching each other. The force of attraction F between them is

(1) $F \propto r^4$ (2) $F \propto r^6$ (3) $F \propto r^2$ (4) $F \propto \frac{1}{r^2}$

2. Two bodies 'A' and 'B' having masses 'm' and '2m' respectively are kept at a distance 'd' apart. A small particle is to be placed so that the net gravitational force on it, due to the bodies A and B, is zero. Its distance from the mass A should be

(1) $x = \frac{d}{1+\sqrt{2}}$ (2) $x = \frac{d}{1+\sqrt{4}}$ (3) $x = \frac{d}{1+\sqrt{3}}$ (4) $x = \frac{d}{1+\sqrt{6}}$

3. Three uniform spheres each of mass 'm' and radius 'r' are placed in contact as shown. Find net force of gravitation on second sphere.



(1) $\frac{5Gm^2}{16r^2}$ (2) $\frac{Gm^2}{16r^2}$ (3) zero (4) $\frac{Gm^2}{r^2}$

4. Find the separation between two massive particles each of mass 5 mg if they experience a gravitational force of 6.66 dyne.

(1) 5 mm (2) 5 μm (3) 5 nm (4) 5 cm

5. An apple falls towards the earth because the earth attracts it. The apple also attracts the earth by the same force. Why do we not see the earth rising towards the apple?

(1) Acceleration of the earth is very large when compared to that of apple.
(2) Acceleration of the earth is equal to that of apple.
(3) Acceleration of the earth is very small when compared to that of apple.
(4) None of these

6. Two spheres of masses m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be

(1) $\frac{F}{3}$ (2) $\frac{F}{9}$ (3) 3F (4) F

7. Gravitational force is a

(1) long range attractive force (2) long range repulsive force
(3) short range repulsive force (4) short range attractive force

8. If the distance between the earth and moon is reduced to half of its original, the gravitational force between them will

(1) become 2 times (2) become 8 times (3) become 4 times (4) become 6 times

9. The gravitational force of attraction between two bodies at a certain distance is 70 N. If the distance of separation between them is doubled, then find the percentage change in force of attraction.

(1) Decreases by 25 % (2) Decreases by 75 %
(3) Increases by 50 % (4) Increases by 75 %

10. Calculate the force of gravity between a 3 kg newborn baby and a 75 kg doctor standing 1 m away.

(1) 3.5×10^{-7} N (2) 6×10^{-4} N (3) 2×10^{-6} N (4) 1.5×10^{-8} N

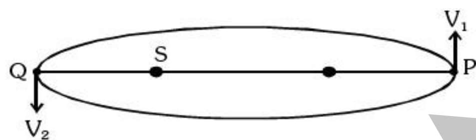
11. The centripetal force on a satellite revolving around the earth is F. The gravitational force of the earth is also F. The net force on the satellite is

(1) 2F (2) zero (3) F (4) F/2

12. According to Kepler's third law, the orbital period T of a planet around the Sun varies with its mean distance r from the Sun as

(1) r^2 (2) $\frac{1}{r^2}$ (3) $r^{\frac{3}{2}}$ (4) $r^{\frac{-3}{2}}$

13. The figure shown below is an elliptical orbit along which a planet revolves round the sun. Let the velocity of planet at P and Q positions be V_1 and V_2 respectively. Then, the possible relationship between magnitudes of V_1 and V_2 is



(1) $V_1 < V_2$ (2) $V_1 = V_2$ (3) $V_1 > V_2$ (4) Cannot be determined

14. Which of the following statements are true?

(i) The orbit of a planet is elliptical with the sun at one of its foci.

(ii) The line joining the planet and the sun sweeps equal areas in equal intervals of time.

(iii) The square of the mean distance of a planet from the sun is proportional to the cube of its orbital period.

(1) Only (i) and (ii) (2) Only (ii) and (iii) (3) Only (i) and (iii) (4) (i), (ii) and (iii)

15. If the distance between the earth and the sun were half the present value then the number of days in a year would have been

(1) 64.5 (2) 129 (3) 182.5 (4) 730

16. If the radius of the earth were to be increased by a factor of 3, by what factor would its density have to be changed to keep 'g' the same?

(1) 3 (2) 1/3 (3) 6 (4) 1/6

17. A body weighs 900 N on the earth. Find its weight on a planet whose density is $\frac{1}{3}$ rd the density of earth and radius is $\frac{1}{4}$ th that of the earth.

(1) 75 N (2) 500 N (3) 62 N (4) 320 N

18. If the radius of the earth reduces by half of the value of the present radius and mass remains same, the acceleration due to gravity

(1) decreases 4 times (2) remains constant (3) increases 4 times (4) decreases 2 times

19. The mass and diameter of a planet are two times those of Earth. If a seconds pendulum is taken to it, the time period of the pendulum in seconds is

(1) $\frac{1}{\sqrt{2}}$ (2) $\frac{1}{2}$ (3) 2 (4) $2\sqrt{2}$

20. The density of a newly discovered planet is twice that of earth. The acceleration due to gravity at the surface of the planet is equal to that at the surface of the earth. If the radius of earth is R, the radius of planet would be

(1) $\frac{R}{4}$ (2) $\frac{R}{2}$ (3) 2R (4) 4R

21. If G is universal gravitational constant and g is acceleration due to gravity, then the unit of the quantity $\frac{G}{g}$ is

(1) kg-m^2 (2) kg/m (3) kg/m^2 (4) m^2/kg

22. The acceleration due to gravity g and mean density of earth ρ are related by which of the following relations? [G = gravitational constant and R = radius of earth]

(1) $\rho = \frac{4\pi g R^2}{3G}$ (2) $\rho = \frac{4\pi g R^3}{3G}$ (3) $\rho = \frac{3g}{4\pi GR}$ (4) $\rho = \frac{3g}{4\pi GR^3}$

23. A spherical planet, far out in space, has a mass M_0 and diameter D_0 . A particle of mass m falling freely near the surface of this planet will experience acceleration due to gravity which is equal to

(1) $\frac{GM_0}{D_0^2}$ (2) $\frac{4mGM_0}{D_0^2}$ (3) $\frac{4GM_0}{D_0^2}$ (4) $\frac{Gm}{D_0^2}$

24. **Assertion :** When a body is thrown up, the acceleration due to gravity at the topmost point is zero.
Reason : The acceleration due to gravity is always directed downwards towards the centre of the earth for a freely falling body.
(1) Both assertion and reason are correct and reason is the correct explanation of assertion.
(2) Both assertion and reason are true but reason is not the correct explanation of assertion.
(3) Assertion is true but reason is false.
(4) Assertion is false but reason is true.

25. A food packet is released from a helicopter which is rising steadily at 3 ms^{-1}. After two seconds how far is the food packet below the helicopter?
(1) 9.8 m (2) 19.6 m (3) 29.4 m (4) 39.2 m

26. A particle is projected vertically upwards from a point A on the ground. It takes t_1 seconds to reach a point B at a height 'h' from A but still continues to move up. If it takes further t_2 seconds from B to the ground again, then find maximum height reached.

(1) $\frac{g(t_1+t_2)^2}{2}$ (2) $\frac{g(t_1+t_2)^2}{4}$ (3) $\frac{g(t_1+t_2)^2}{6}$ (4) $\frac{g(t_1+t_2)^2}{8}$

27. A stone is dropped into a well in which the level of water is h below the top of the well. If 'v' is velocity of sound, the time T after which the splash is heard is given by

(1) $T = \frac{2h}{v}$ (2) $T = \sqrt{\frac{2h}{g}} + \frac{h}{v}$ (3) $T = \sqrt{\frac{2h}{v}} + \frac{h}{g}$ (4) $T = \sqrt{\frac{h}{2g}} + \frac{2h}{v}$

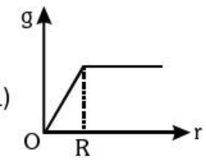
28. If we neglect the air resistance, the time taken by a freely falling body to reach the ground will not depend upon
(1) Height of free fall (2) Acceleration due to gravity
(3) Mass of the body (4) Speed with which body strikes the ground

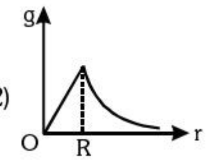
29. Two rubber balls of the same size are both dropped on the Earth and on the Moon. One ball is solid, and one is hollow. The approximate gravitational field strength on the Earth is 10 N/kg and on the moon is 1.7 N/kg. Which ball has the greatest force acting on it?

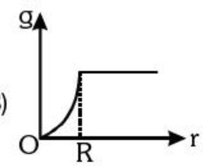
	Type of ball	Where dropped
(1)	Hollow	On the Earth
(2)	Hollow	On the Moon
(3)	Solid	On the Earth
(4)	Solid	On the Moon

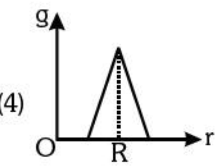
30. A particle is taken to a height of $2R_e$ above the earth's surface, where R_e is the radius of the earth. If it is dropped from this height, its acceleration will be
(1) 3.1 m/s^2 (2) 5.1 m/s^2 (3) 1.1 m/s^2 (4) 2.1 m/s^2

31. Variation of 'g' w.r.t. height or depth is correctly represented by

(1) 

(2) 

(3) 

(4) 

32. If the change in the value of 'g' at a height h above the surface of the earth is the same as at a depth x below it, when both x and h are much smaller than the radius of the earth, then the relation between x and h is

(1) $x = h$ (2) $x = 2h$ (3) $x = 3h$ (4) $x = 4h$

33. At what height should a body be taken above the surface so that the acceleration due to gravity becomes 1% of its value at the surface of the earth (of radius R)?

(1) 4R (2) 6R (3) 9R (4) 100R

34. **Assertion :** A tennis ball bounces higher on hills than in plains.

Reason : Acceleration due to gravity on the hill is greater than that on the surface of earth.

(1) Both assertion and reason are correct and reason is the correct explanation of assertion.

(2) Both assertion and reason are true but reason is not the correct explanation of assertion.

(3) Assertion is true but reason is false.

(4) Assertion is false but reason is true.

35. How much below from the surface of the earth does g become half of its value at the earth's surface? (Assume earth to be a homogeneous sphere of radius R meter)

(1) R (2) $\frac{R}{2}$ (3) 2R (4) $\frac{R}{4}$

36. If 'R' is the radius of earth, the height at which the weight of a body becomes $\frac{1}{4}$ th of its weight on the surface of the earth is

(1) 2R (2) R (3) $\frac{R}{2}$ (4) $\frac{R}{4}$

37. Purchasing 1 kilogram of sugar will be profitable at

(1) equator (2) poles (3) at $27\frac{1}{2}^\circ$ latitude (4) $57\frac{1}{2}^\circ$ latitude

38. A simple pendulum has a time period T_1 when on the earth's surface and T_2 when taken to a height R above the earth's surface, where R is the radius of the earth. The value of $\frac{T_2}{T_1}$ is

(1) 1 (2) 2 (3) 3 (4) 4

39. At what height is the value of 'g' half that on the surface of earth? (R = radius of the earth)

(1) 0.414R (2) R (3) 2R (4) 3.5R

40. A body is taken to a height of $(\sqrt{2}-1)$ R_e above the earth's surface, where R_e is the radius of the earth. If it is dropped from this height, its acceleration will be :

(1) 9.8 m/s^2 (2) 6.5 m/s^2 (3) 4.9 m/s^2 (4) 2.5 m/s^2

41. A spring balance is graduated on sea level. A body of mass 1 kg is weighed at consecutively increasing heights from the earth's surface, then what would be the weight indicated by the balance?

(1) Weight will go on increasing continuously (2) Weight will go on decreasing continuously

(3) Weight will remain same (4) Weight will first increase and then decrease

42. 1 kg wt is equal to

(1) 9.8 N (2) 980 N (3) 98 N (4) none of these

43. The mass of a body at the centre of Earth is

(1) zero (2) unity (3) remains unchanged (4) infinity

44. The weight of a rock on the moon is 200.6 N. What is its mass on the earth?
(Take g of earth = 9.8 m s^{-2}, g of moon = 1.7 m s^{-2})

(1) 20 kg (2) 118 kg (3) 200 kg (4) 1180 kg

45. A man of weight W is standing on a lift which is moving upwards with an acceleration 'a'. The apparent weight of the man is

(1) $W\left(1+\frac{a}{g}\right)$ (2) $W\left(1-\frac{a}{g}\right)$ (3) $W\left(1-\frac{a^2}{g^2}\right)$ (4) W

46. If the earth loses its gravity, then for a body

(1) Weight becomes zero but not the mass
(2) Mass becomes zero but not the weight
(3) Both mass and weight becomes zero
(4) Neither mass nor weight becomes zero

47. A person in a lift will experience weightlessness when the lift moves

(1) down with an acceleration equal to 'g'
(2) up with an acceleration equal to 'g'
(3) up with a constant velocity
(4) down with an acceleration equal to 'g/6'

48. **Assertion :** If an earth satellite moves to a lower orbit, the speed of satellite increases.

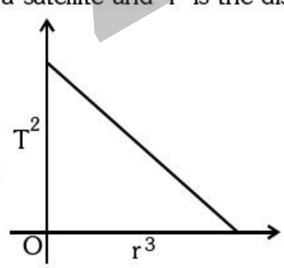
Reason : The speed of satellite is a constant quantity for all orbits of earth.

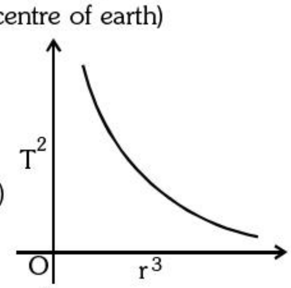
(1) Both assertion and reason are correct and reason is the correct explanation of assertion.
(2) Both assertion and reason are true but reason is not the correct explanation of assertion.
(3) Assertion is true but reason is false.
(4) Assertion is false but reason is true.

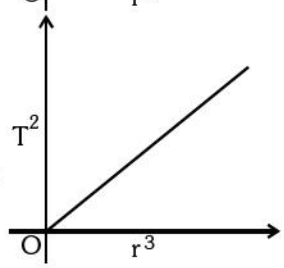
49. A satellite which is geostationary in a particular orbit is taken to another orbit. Its distance from the centre of earth in new orbit is 2 times that in the earlier orbit. The time period in the second orbit is

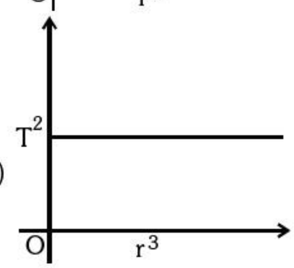
(1) 4.8 hours (2) $48\sqrt{2}$ hours (3) 24 hours (4) $24\sqrt{2}$ hours

50. Which of the following graphs is true for the motion of a satellite revolving round the earth? ('T' is the time period of a satellite and 'r' is the distance of the satellite from the centre of earth)

(1)


(2)


(3)


(4)


51. A satellite goes round the earth along a circular path with its centre at the centre of the earth and the radius equal to the distance between the centre of the earth and the satellite. If M is mass of the earth, r is radius of the circular path and G is universal gravitational constant, the period of revolution of the satellite will be

(1) $2\pi\sqrt{\frac{r^3}{GM}}$ (2) $2\pi\sqrt{\frac{GM}{r^3}}$ (3) $2\pi\sqrt{GMr^3}$ (4) zero

52. The period of a satellite in a circular orbit around a planet is independent of

(1) The mass of the planet (2) The radius of the planet
(3) The mass of the satellite (4) All of the above

53. The ratio of time periods of two satellites revolving around the earth in the orbits of radii 1 : 4 will be

(1) 1 : 4 (2) 4 : 1 (3) 1 : 8 (4) 8 : 1

54. **Assertion :** The time period of geostationary satellite is 24 hours.
Reason : Geostationary satellite must have the same time period as the time taken by the earth to complete one rotation about its axis.
(1) Both assertion and reason are correct and reason is the correct explanation of assertion.
(2) Both assertion and reason are true but reason is not the correct explanation of assertion.
(3) Assertion is true but reason is false.
(4) Assertion is false but reason is true.

55. The escape velocity of a particle of mass m varies as

(1) m^2 (2) m (3) m^{-1} (4) m^0

56. The escape velocity from the earth's surface is V_e. The velocity of a satellite while orbiting just above the earth's surface is V_0. Then the relation between these velocities is

(1) $V_e=\sqrt{2}V_0$ (2) $V_e=\frac{1}{\sqrt{2}}V_0$ (3) $V_e = V_0$ (4) $V_e = 2V_0$

57. **Assertion :** Two different planets have same escape velocity.
Reason : Value of escape velocity is a universal constant.
(1) Both assertion and reason are correct and reason is the correct explanation of assertion.
(2) Both assertion and reason are true but reason is not the correct explanation of assertion.
(3) Assertion is true but reason is false.
(4) Assertion is false but reason is true.
(5) Both assertion and reason are false.

58. Knowing that the mass of moon is 1/81 times that of earth and its radius is 1/4 the radius of earth. If the escape velocity at the surface of the earth is 11.2 km/s, then the value of escape velocity at the surface of the moon is

(1) 2.5 km/s (2) 0.14 km/s (3) 5 km/s (4) 8 km/s

59. Time period of a simple pendulum in a satellite is

(1) infinite (2) zero (3) 2 sec (4) cannot be calculated

60. Reason of weightlessness in a satellite is

(1) Zero gravity (2) No atmosphere
(3) Zero reaction force by satellite surface (4) None of the above

ANSWERS

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	1	3	3	3	4	1	3	2	4	3	3	1	1	2	2	1	3	4	2
Que.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	4	3	3	4	2	4	2	3	3	3	2	2	3	3	2	2	1	2	1	3
Que.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	2	1	3	2	1	1	1	3	2	3	1	3	3	1	4	1	5	1	1	3